Battelle
The Business of Innovation

Market Opportunity Assessment for Direct Hydrogen PEM Fuel Cells in Transition Markets

Kathya Mahadevan

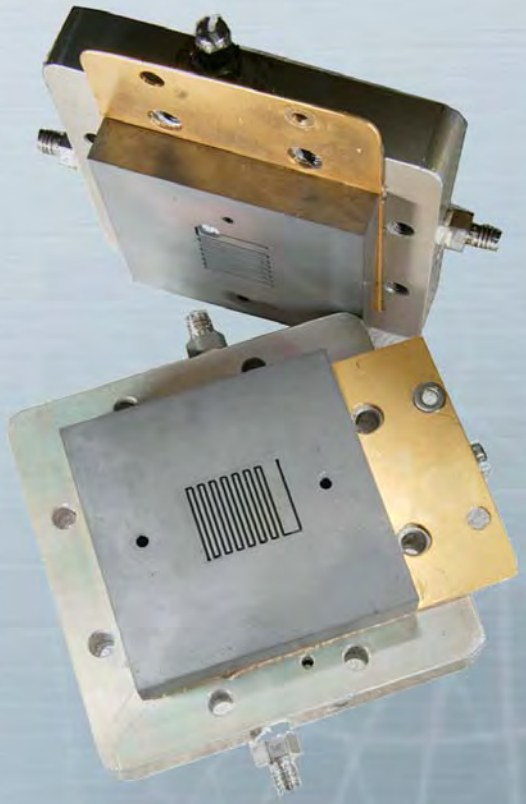
Battelle
July 19, 2006

Objectives

To assist DOE in the development of fuel cell systems by providing an analysis of the technical, economic and market drivers of PEM fuel cell adoption. 2006 plans include -

- Market segmentation of direct hydrogen PEM fuel cells (H-PEMFC) in the 1 – 250 kW size range to 2015 and analysis of near-term, mid-term, and long-term transition opportunities for H-PEMFC

- Market opportunity assessments for H-PEMFC in near-term transition markets (2008)

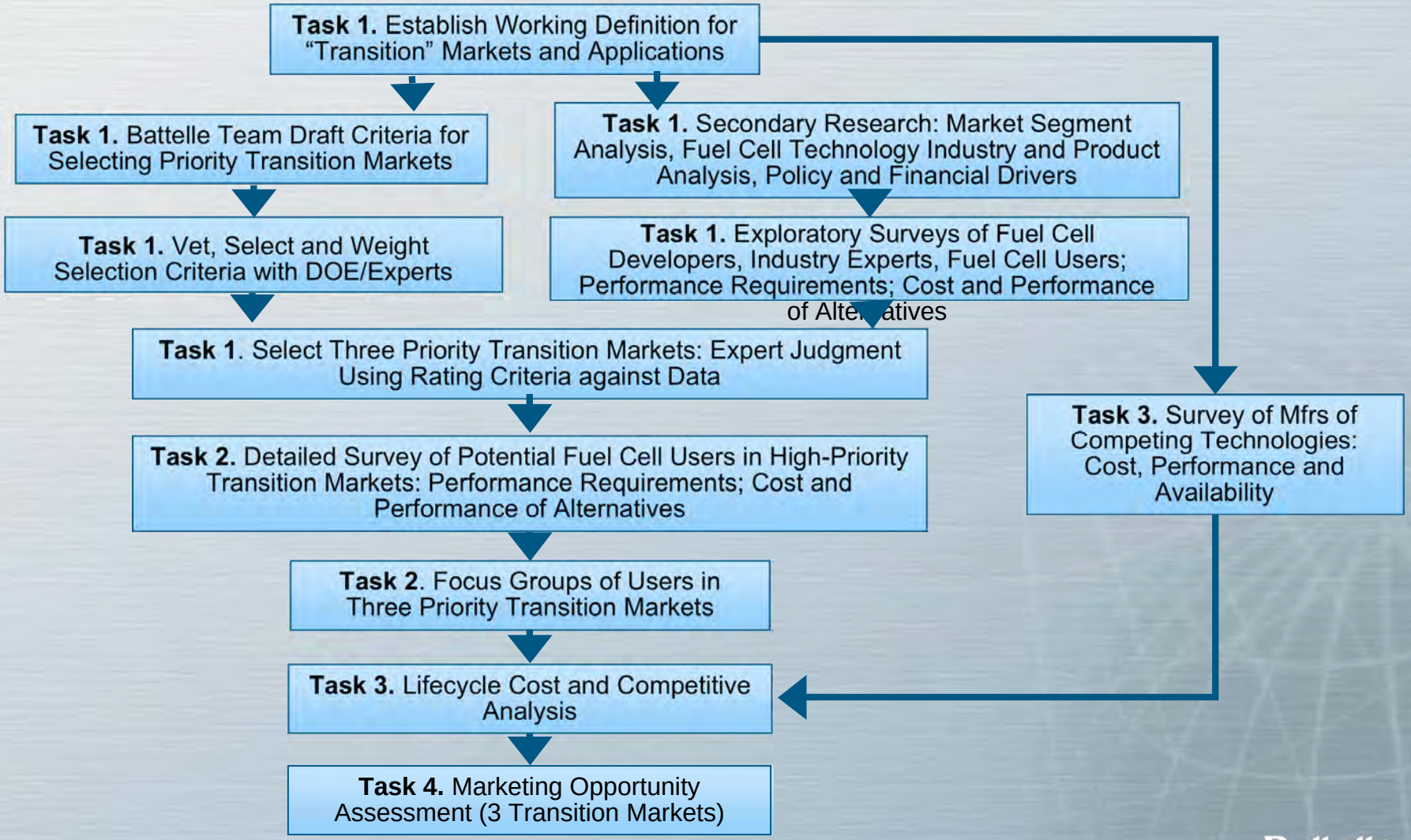


2006 Scope – Transition Market Analysis

Identify and prioritize three transition markets (TM) for H-PEMFC to 2008

- TM are “pre-automotive” markets that utilize components and underlying technologies similar to automotive H-PEMFC.
- Segment and develop understanding of user requirements in the Federal and private sector TM
- Identify 3 TM for H-PEMFC potential adoption by 2008
- Also determine TM between 2008-2012 and past 2012
- Perform competitive analysis (cost and quality) of existing H-PEMFC (considering improvements highly likely by 2008) and alternative technologies
- Develop value propositions, estimate market penetration rates and provide a market opportunity assessment for H-PEMFC
- Support communication of the findings

Research Plan



Current Status of the PEM Fuel Cell Industry

- Commercial products for backup power are available (< 30 kW)
- Specialty vehicle and portable power products are pre-commercial (<85 kW)
- Only one grid parallel reformer based product is available (<10 kW)
- Fuel cell company revenues are declining and investor interest in fuel cells in waning
- For PEM fuel cell power systems, early adopters have emerged with in telecom, utilities, and government
- Fuel cell companies and component developers need to see increased revenues from fuel cell sales to support continued R&D for technological breakthroughs in automotive applications and sustain interest of investors and the general public

Commercially Available Stationary PEM Fuel Cell Products

Manufacturer (Product)	Application	Size	Retail Price*
APC (InfraStruXure ISX-FCXR10-30)	Backup to computer systems	30 kW	$25,000
IdaTech (ElectraGen™ 3 and ElectraGen™ 5)	Telecommunications, utilities	3 - 5 kW	Unknown
Plug Power (GenCore®)	Backup power for wireless and wireline providers	5 kW	$17,500
ReliOn (T-1000™ and T-2000™)	Backup power for telecommunications, utility and government sectors	1 - 2 kW	$4,500-9,000
Plug Power (GenSys™ 5C and GenSys™ 4C)	On-site grid parallel CHP for residential and light commercial applications	2.5 – 5 KW	$55,000

*Retail price does not include warranty offered by manufacturers

Commercially Available Direct Hydrogen PEM Fuel Cell Modules for Specialty Vehicles*

Manufacturer (Product)	Application	Size	Retail Price
Hydrogenics (HyPM®)	Materials handling equipment, commercial vans, transit buses, neighborhood electric vehicles	8.5 kW, 13 kW, 17 kW, 66 kW	Unknown (Is supplied to OEM for integration into product)
Ballard (Mark9 SSL™, Mark 902)	Light-duty vehicle applications	4 kW, 8.8 kW, 13.2 kW, 19.3 kW, 85 kW	Unknown (Is supplied to OEM for integration into product)
Nuvera (PowerFlow™)	Industrial Vehicles and Equipment	5 kW	Unknown (Is supplied to OEM for integration into product)

*Note: while PEM fuel cell modules are available, currently no PEM fuel cell integrated specialty vehicle products are commercially available. Numerous products are in testing and it is anticipated that commercial products will be available for forklifts, airport tugs, turf maintenance equipment, scooters, and unmanned aerial and underwater applications.

Likely Path of Transition to 2015

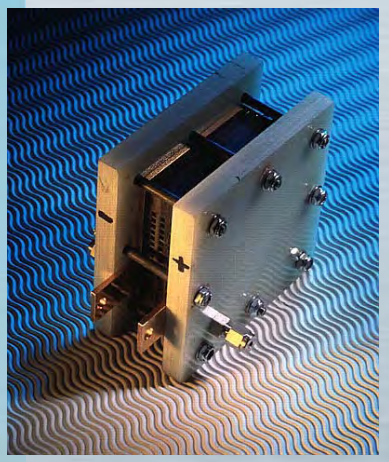
2008

Backup Power

Specialty Vehicles

Portable/Auxilliary Power

Fleet Vehicles



Grid Independent/Parallel Power

2015

Light Duty Vehicles

Heavy Duty Vehicles

Definition of Transition Applications and Markets

Transition applications and markets for H-PEMFC are defined as those applications and market opportunities that support the development of technology and the industry necessary to ensure the commercialization of automotive H-PEMFC by 2015.

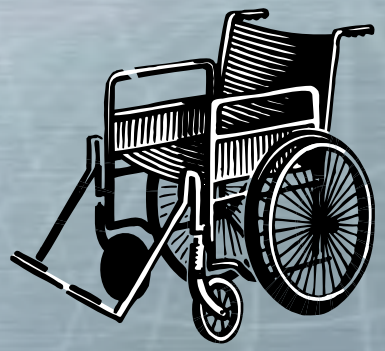
Transition markets for H-PEMFC can be “pre-automotive” markets that utilize components and underlying technologies similar to automotive H-PEMFC. Transition markets are composed of applications that have some operational characteristics similar to automotive H-PEMFC.

Transition markets for H-PEMFC can also be those markets with early adopters for backup power and grid independent/parallel power applications. It is anticipated that increased demand from these markets could decrease cost of components, maintain investor interest, and facilitate the development of a supplier base of H-PEMFC technology.

Transition Applications and Markets – Specialty Vehicles

Specialty Vehicles

- Lift Trucks/Forklifts
- Airport Tugs
- Automated Guide Vehicles
- Mining Vehicles
- Burden/Personnel Carriers
- Golf Carts
- Turf Maintenance Vehicles
- Commercial Sweepers
- Ice Resurfacers
- Wheelchairs
- Lawn Mowers
- Unmanned Undersea Vehicles
- Unmanned Aerial Vehicles
- Motorized Bicycles/Scooters



Transition Applications and Markets – Stationary Power *(continued)*

Back-up Power Applications

- Telecom
- Finance
- Data Centers
- Grocery Stores
- Casinos
- Hotels
- Ski-Parks
- Amusement Parks

- Healthcare
- Railways
- Airports
- Water and Wastewater Distribution
- Electric Utility substations

- Food Manufacturing
- Chemical Manufacturing
- Pharmaceuticals
- Metals Processing and Refining
- Computer and Electronic Products
- Oil and Gas Manufacturing
- Transportation Equipment Manufacturing

Transition Applications and Markets – Stationary Power *(continued)*

Back-up Power Applications **(continued)**

- Federal Agencies (back-up for critical communication needs)
  - DOD – U.S. Army, U.S. Navy, U.S. Air Force
  - DOT - Federal Aviation Administration, Federal Railroad Administration
  - DHS – U.S. Coast Guard, Federal Emergency Management Agency
  - DOC – NOAA National Weather Service
  - NASA
  - NRC
  - DOE
  - EPA

- State and Local Departments of Emergency Response
  - First Responder Stations and Call Centers
  - Emergency Centers (Emergency Shelters)
  - Emergency Communications Centers
  - Police Stations
  - Fire-houses
- National Parks

Requirements	Airport Tugs	Forklifts
Current Mode of Operation	Electric and ICE systems	Electric and ICE systems
Operation and Maintenance Requirements	Every 150-200 hours	Every 200-250 hours
Safety Concerns with Current Technologies	None provided precautions are taken	None provided precautions are taken
Most Important Factors for Selecting Technology	Reliability, lifetime of unit, annual operating cost, and ease of use	Reliability, lifetime of unit, fuel availability, capital cost
Performance of Current Technologies	Good – ICE systems Very good – batteries	Not so good – batteries Good – ICE systems
Concerns with Current Technologies	Spills and leaks; hazardous emissions; too long to refuel and recharge; inconvenient to recharge; unsafe	Inconvenient to recharge; causes leaks and spills; takes to long for charging, cooling, and equalizing the batteries; hazardous emissions
Satisfaction with Current Technology	Very good - reliability, start-up time, time between refueling, ease of use, and fuel availability Good – capital cost, operation and maintenance costs, and lifetime	Very good – reliability, capital cost, lifetime, ease of use, and fuel availability Good – operation and maintenance costs, start-up time, time between refueling
Alternatives Considered	Yes – Alternative Fuels, Fuel Cells	Yes – Fast Chargers, Fuel Cells
Decision Drivers to Purchase PEM Fuel Cells	Environmental concerns, government incentives, cost incurred from downtime, dissatisfaction with current mode of operation, track record of others using it, efficiency of PEM fuel cells	Cost incurred from downtime, efficiency of PEM fuel cells, environmental concerns, availability of government incentives, track record of others using PEM fuel cells
Purchase Decision Drivers	Return on investment, Government Incentives	Return on investment

Rating Criteria Applied for Priority Transition Market Selection

Market Criteria

- H-PEMFC offer unique value to market segment not met by competing technologies
- H-PEMFC product characteristics and their potential benefits must fit user requirements (high priority needs)
- Sufficient market size and growth potential of the market segment to ensure current and continued fuel cell adoption
- Cost of reaching the market, including product development and marketing, is reasonable
- H-PEMFC products are available for immediate application, or can be developed over the short-term

Likely Transition Markets to 2015

2008

- Telecom
- Forklifts
- Airport Tugs
- Emergency Response

2008 - 2012

- Healthcare
- Railways
- Water and Wastewater Utilities
- Electric Utilities
- Government
- Airports
- Finance
- Data Centers
- Manufacturing – Chemical, O&G, Pharmaceutical

Twenty-year Lifecycle Cost Analysis

Comparing 5 kW fuel cell systems to battery and generator systems for backup power applications at remote telecom sites

5 kW Fuel Cell vs. Battery Backup Power	Fuel Cell Total Cost $	Battery Total Cost $
Capital Cost	30,000	28,800
Installation	7,000	3,000
Fuel	1,999	0
Charger, Load Transformer & Electricity	0	1,880
Generator	0	8,800
Demurrage	3,066	0
Batteries	1,600	16,000
Disposal	100	400
O&M	2,000	13,900
Cash	45,765	56,980
Net Present Value (NPV)	$27,179	$28,172

* Tax impacts are not included. Assumed 15 year fuel ell life and 5 year battery life

Key Findings

- PEM fuel cells are a good fit for those applications requiring longer run-times
- PEM fuel cells offer ease of use, and can be applied in applications where batteries are difficult to change out and recharge
- PEM fuel cells have no emissions, and can be used in those applications looking to replace diesel generators
- Due to lack of data on field reliability PEM fuel cells will be used initially to backup batteries in critical applications to ensure redundancy
- Likely applications for PEM fuel cells in backup power are
  - Communications
  - Controls and Monitoring
  - Emergency Lighting
- Limited examination of Federal users indicates that drivers for adoption of PEM fuel cells differ from private sector (not necessarily a business decision – capital cost, sustainability, energy security)
- Early adopters (in agencies other than Army and Navy) based on need for longer run times include FAA, NOAA, USCG

Energy Bill – 2006 Stationary Fuel Cell Requirements for Federal Agencies

- SEC. 783 requires federal procurement of stationary, portable, and micro fuel cells
- "Not later than January 1, 2006, the head of any Federal agency that uses electrical power from stationary, portable, or microportable devices shall lease or purchase a stationary, portable, or micro fuel cell to meet any applicable energy savings goals"
- Purpose is to stimulate market acceptance
- Appropriations required to pay or share cost of leased or purchased systems

Specific Project Input Requested

From Federal Agencies

- Potential transition markets and applications for H-PEMFC to 2015
- User requirements for H-PEMFC in promising transition markets in the near-term (2008)
- Likelihood of adoption of H-PEMFC in the near-term (2008)
- Strategies to facilitate commercialization of H-PEMFC in key transition markets

Acknowledgements

DOE

- **Kathi Epping, EERE, HFCIT Fuel Cell Team**
- Steve Chalk, EERE, HFCIT Program Manager (*on detail currently*)
- Joanne Milliken, EERE, HFCIT Acting Program Manager
- Valri Lightner, EERE, HFCIT Fuel Cell Program Team Leader
- Sigmond Gronich, EERE, HFCIT Technology Validation Team Leader

Battelle Project Staff

- Harry Stone – Principal Investigator
- Darrell Paul – Program Manager
- Kathleen Judd – Market Analyst

Contact Information

Kathya Mahadevan
Research Scientist
Battelle
505 King Avenue
Columbus, Ohio 43235
mahadevank@battelle.org
Tel No - 614-424-3197
Fax No – 614-458-3197
www.battelle.org